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MILITARY GEOLOGY

Chapter 16. WORK IN VARIOUS LANDSCAPE ZONES

[Figures referred to herein are not reproduced but are available in the original document at the US Geological Survey.]

The military geologist is obliged to work in the greatest variety of conditions of relief, climate and geological structure. That variety determines the methods to be adopted for carrying out military prospecting and military-engineering work. Tactical requirements change depending upon the geological conditions of the area.

Regions which are characterized by homogeneous relief features are classified according to combination and interrelationship and by their connection with the geological structure and the physico-geological processes which are active at the present time and were manifest in the fairly recent past. Such recurrent classifications of relief features, connected with the general processes which give rise to them, have been called geomorphological landscapes.

The geological structure and interdependence of the separate elements become clear to the geologist when he makes an accurate determination of the origin of the relief elements. Thus, by taking account of the depth of the water table he can make corresponding deductions concerning the possibility for military-engineering construction. However, an accurate solution to a number of questions, touching upon such problems as, for example, water supply, terrain traversability, and camouflage is only possible with a strict accounting of all elements of the geographic landscape and, above all, of climatic factors, soil, vegetation, etc. The calculation of the complex of geological factors in the solution of military-engineering problems, and the exposition of the peculiarities of their influence on military-geological work in the various regions presents a new, very important field -- regional military geology.

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At the present moment, the scope of this field and the range of problems which it should embrace are only dimly visible. Many problems require systematization of material, scientific analysis, and critical evaluation.

The territory of the Soviet Union, which occupies one-sixth of the land surface of the globe, and which is characterized by an extreme variety of geological structure extending from north to south for many thousands of kilometers and embracing the most varied climatic zones, possesses exceptionally varied combinations of geological factors, which influence military-geological and military-engineering work. In this respect, other countries are distinguished by a much greater uniformity and fall into few landscape zones. That is why the military-geological questions under consideration, which are called regional problems, naturally had to arise in our country and receive due elaboration there.

The peculiarities of the geologist's work in the principal landscape zones are examined in the following sections.

I. WORK IN A GLACIATED REGION

A. Region of Glacial Denudation

A region of glacial denudation is characterized by a comparatively high relief, by the predominating occurrence of original strata (TN: strata found at the location of their formation) and the wide distribution of friable deposits of glacial complex of very different thicknesses. The forms of relief which are developed include both the denudate furrowings worked out of the original strata and connected with the processes of glaciation, and, to a lesser extent, the accumulated deposits, conditioned by agglomerations of original rock, of the fluvio-glacial or of the lake type. A good example of this might be the territory of Scandinavia, Finland, and the Karelo-Finnish SSR. This region is basically greatly complicated by the dislocated, pre-Cambrian crystallized layers, which either outcrop on the earth's surface or lie very near the surface, being covered by friable, Quaternary layers. The whole northern part of this region presents a typical tundra, which is characterized by an almost total absence of forest. Areas farther south, in the Siberian forest region, are distinguished by the prevalence of coniferous forests of spruce, larch, fir, cedar, and pine.

Along the coastal strip in the north, the region presents a broken flatland, dropping off sharply into the sea. Certain sections are considerably elevated above sea level -- up to 1,000 meters and more. The whole region is characterized by an abundance of lakes and marshes. The rivers have many rapids and cascades.

Characteristic of the region are such relief features as gouged-out lakes, "baran'iiby" [sheep's foreheads], eskers, drumlins, terminal moraines, etc. In accordance with the climatic zone of this region, soils of the podzolic type are predominant. Marshes with a thin, peaty covering are widespread. Subsoil waters generally lie close to the ground surface and come up as surface or swamp water. In composition, these waters are often characterized by a high organic-matter content but a quite insignificant amount of mineral salts. On the crust of the erosion of original strata, interstitial waters are developed.

All the above-mentioned geological factors create extraordinary conditions for geological work and the erection of military-engineering construction.

In view of the sporadic distribution of friable deposits and the great strength of the original layers lying under them, careful evaluation of the sites is required in fortification construction. This is especially true in underground structures 6 - 10 meters deep. It is a difficult problem to find

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places where the subsoil waters will not disturb such structures.

When a rocky stratum occurs at a high water-table level, underground mine warfare is almost impossible. The places where it is possible must be pointed out by the geologist.

In the choice of lines of defense, it is necessary to take into account the abundance of natural barriers, such as numerous lakes, swamps, and forest masses. Defensive constructions should reinforce natural obstructions and should be built mainly on lines of communication and within the limits of a defile between natural obstructions.

Therefore, one of the primary duties of the geologist is to clarify the engineering-geological peculiarities of such sectors. The presence of various locally available construction materials (boulders, quarrystone, rubble, gravel, sand, peat, etc.), together with a great quantity of sandy material, facilitates construction and reduces the outlay of concrete and reinforced concrete. A large quantity of rock deposits permits making antitank obstacles such as stone posts and obstructions.

The search for construction materials is facilitated by the geomorphological peculiarities of the area.

From the viewpoint of terrain traversability, natural barriers are of great importance, as is demonstrated by the fact that, in many cases, it is possible to cross lakes and swamps only under winter conditions. The geologist must pay especial attention to swampy masses, which must be studied from the point of view of traversability, and to lake shores, whose geomorphology will play a decisive part in offensive and defensive operations. Forestation and swampiness require the execution of great and complicated military road construction.

Military hydrotechnical measures can also be taken successfully in strengthening zones of artificial water barriers. However, the installation of first-class hydrotechnical constructions requires a great amount of time and is applicable only in the advance preparation of a locality for defense. Their geological basis requires detailed geological investigation. Third-class (hasty) hydrotechnical constructions have little significance, since rivers with a deep, swift course present in themselves a sufficient barrier. It is the duty of the geologist to discover such places where the construction of third-class dams would be possible as far as geological conditions are concerned and logical from the tactical point of view.

The work of draining trenches of the various fortification constructions, airfields, military roads, etc., is of great significance. A detailed study showing the geological and hydrogeological structure with an examination of the source of swamping waters is necessary for this work.

There is no difficulty in supplying water for troops, because of the accessibility of the water table and the abundance of surface water. The presence of large quantities of organic matter in swamp waters dictates the use of the lower-lying water of the first water-bearing stratum, which may be connected with the surface water or be separate from it. In many cases it is possible to use the deeper waters from the friable Quaternary deposits, which fill in the hollows of the relief of the original strata, by digging artesian wells in places where the water has sufficient force. In such cases, the water frequently appears to exert pressure and is distinguished by its good quality and sufficient volume.

Camouflage in the conditions indicated above is greatly facilitated by the widespread occurrence of forest masses.

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For purposes of deception, false eskers, terminal-moraine walls, piles of boulders, etc., can be built.

The relief and the subsoil water level must fulfill many requirements to render a site suitable for building an airfield landing strip -- a fact which greatly complicates the situation. Lakes provide good and numerous landings for seaplanes. In winter, suitable landing strips can be found in abundance.

Aerial-photographic material for the region can be satisfactorily interpreted. However, meteorological conditions restrict aerial photography at certain times of the year. Photographs taken in winter provide little material for the geologist. Photographs taken in summer bring out the meso- and microrelief features and, depending on the microzonality of the vegetation cover, they permit conclusions to be drawn concerning the changes in the water and ground factors in the region.

The military operations of the Red Army against Finland in 1939 - 1940 provide an interesting example, illustrating the influence of natural factors on the technical preparation of defensive constructions.

According to the description of Colonel-General of Engineers A. Kherenov, Hero of the Soviet Union, the Finns had almost no strong, reinforced-concrete construction on the USSR border, since the area itself, covered with dense virgin forests, lakes, and swamps intersecting hills, mountains, and crags, was so advantageous for defense that simple reinforcement by field fortifications brought vast defensive advantages. Basic positions lay along the main roads, lateral roads, etc., but the swamps, forests, and mountains secured these positions from flank envelopment or attacks from the rear.

Field-type fortifications consisted of platoon, regiment, and battalion defensive areas, with antipersonnel and antitank obstructions in front and on the flanks.

The defensive areas were equipped with rifle and machine-gun emplacements, trenches connecting them with the rear, gun emplacements, and dugouts for personnel. The covering of the dugout sometimes consisted of as many as eight layers of timber covered with earth and stones.

All of these fortifications, as a rule, were built beforehand. The emplacements were well camouflaged. Observation points, machine-gun nests and sometimes even rifle pits were protected by an antifragmentation covering.

After all these natural difficulties had been taken into account, the Mannerheim Line was built to the Karelian Isthmus, presenting what was considered by the Finnish command and foreign military observers to be an invulnerable and invincible stronghold, which, however, was broken through by the Red Army.

During the offensive on the Viipuri [Vyborg] position in the war with Finland, the Soviet forces also encountered a great organized system of terrain-flooding, in which the enemy used the water of the Saimaa Canal, which was dug in 1844-1859 and rebuilt in 1934-1939, and in which 12 wide locks had been made.

The canal begins at the Bay of Lauritsala in the southern part of Lake Saimaa and empties into the Gulf of Finland through Cummenvederpohja Bay. The canal is 59.3 kilometers long. The total difference in water level between Lake Saimaa and the Gulf of Finland is 75.9 meters.

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For flooding the eastern and southeastern parts of the Saimaa Canal system, the White Finns built an isolated water-pressure dam in the neck [gorge ?] of the Suomenvedenpohja, which is farther south than Yuustykh. That dam was relied on for flooding the area in two successive instances. In the first case, the water of the canal, retained by the dam, rose and forced its way through the firth of Lake Lepelen into Lake Kopatilen, flooding the valley of the Peron River. The readings went from 1.3 meters to 3.8 meters, a rise of 2.5 meters. In the second case, after flooding a sector of the area, the water-pressure dam burst, and the whole mass of water was directed into Suomenvedenpohja in a violent stream. It broke up the ice and flooded the lowland and part of Vyborg.

In the Soviet-Finnish War, the Finns set about flooding the eastern and southeastern parts of the Vyborg area in the beginning of February, 1940. The water spread over an area approximately 30 kilometers long and 6 kilometers wide. The flooded area approached in places to within 5 kilometers of Vyborg.

B. Region of Glacial Accumulation

The presence of complicated combinations of Quaternary deposits reaching thicknesses of 50 to 100 meters, and in certain cases 200 meters and over, is characteristic of regions of glacial accumulation from the point of view of geological structure.

Either the hard Paleozoic strata or the soft, predominantly Tertiary formation serves as the bed of Quaternary deposits in the European region of glacial accumulation.

Mesozoic and Paleozoic strata are found as separate sections and islands in certain places in the Mountains of Central Germany, in the territory of Esthonia, Latvia and the northwestern parts of the Soviet Union at depths of from 10 to 50 meters (in other places at considerably greater depths). With respect to structure, the original strata have a slight unilateral slant, forming in various places favorable conditions for the accumulation of artesian and semiartesian waters.

The relief of this area bears all the traits of accumulative glacial activity and represents a basic, morainic landscape with a superimposed, glaciated, hydrographic system, terminal moraine landscape, and the presence of "kamy" [?], drumlins, eskers, etc. In most places, traces are found of several freezings which have left intricate complexes of morainic, intermorainic, fluvio-glacial, lake, and lake-marsh deposits with comparatively slight alluvial deposits.

All these deposits are characterized by a great variability of granular formation, various degrees of hardness and porosity, different mineral composition, etc. These differences in properties necessitate equally varied types of constructions.

The region of glacial accumulation in Europe is related to woodland and woodland-plains zones, is covered with mixed forests, podzol soil, and abounds in marshes and lakes. The depth of the water table is usually not great; the water is distinguished by its good quality.

The ground conditions of the zone of glacial accumulation permit the execution of fortification constructions, either with shallow foundations or of trench and underground types. The interstratification of water-resisting and water-permeated strata compel attention to the presence of subsoil water, which may be located at various depths and may have varying peculiarities.

Water under pressure may often be encountered; therefore, one of the geologist's problems is to establish the geological structure of the area

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and isolate the water-bearing strata, their depth of occurrence and peculiarities.

Frequently, intramorainic and intermorainic sandy layers are permeated with water and produce quicksands. It is especially necessary to discover them when planning trenches or underground constructions. The complex of soils of a given area is extremely varied in its composition and nature, and it is difficult to account for it completely. A detailed exploration is necessary during construction work. Such exploration may serve as a safeguard against many unforeseen eventualities and vexations. Especially great attention is required in constructing military roads in sectors where peaty and marshy ground enters into the composition.

Most often, the water table shows up near the ground surface. Accordingly, in such sectors only the lightest fortifications or those of incomplete profile [sic] or those with complete embankment breastworks are constructed.

The study of swampy sectors is carried out with the aid of soundings which clarify the following questions: stratigraphy of the swampy or peaty deposits, the strength of peaty grounds, their character, degree of decomposition, relief of the bottom of the swamp and character of the strata composing it.

The geologist must ascertain the type of the swamp, its origin, and its sources of feeding. Questions of terrain traversability require knowledge of the paragenetic combination of the grounds (TN: It is not clear whether "ground" is used in sense of "floor" or "soil ") and forms of relief. By establishing and distinguishing the various elements of a given landscape and their interrelationship, the geologist facilitates the choice of cross-country routes of march, lateral roads, etc.

When rubbly clay or clayey soil are being dealt with, road surfaces are subject to swelling in proportion to the water permeability of the soil. Marshy masses, which are found abundantly in zones of glacial accumulation can cause many unforeseen difficulties.

Marshy grounds are characterized by their tendency to sink under road fills [mounds, banks] and other constructions (for instance, under gun emplacements).

Deformation of a roadbed on a peaty foundation most often occurs under the influence of pressure, as the result of which the following occur: (1) The shrinking of the peat, (2) the bending and stretching of the peaty strata, (3) the spreading of the peat and sapropelites, (4) the shearing off and fracturing of the peaty carpet.

Analogous deformation is produced by dynamic stress under heavy artillery platforms on swampy grounds. In order to install heavy guns on marshy soil, the top layer is removed, drainage ditches are dug, and a mound [a fill ?] of gravel, rubber, or coarse sand of sufficient mass is made on the platform.

Water barriers, particularly those having tactical importance (third class), may be widely constructed in regions characterized by the geomorphological landscape described here. The geological structure and the minor drop of the river-valley bottoms facilitates the construction of tactical dams for the creation of water obstacles and flooding. In a great many cases, the occurrence of clayey, water-resistant soils necessitates drainage work to carry off the surface and subsoil waters during various types of military-engineering work (fortification construction, military roads, airfields, etc.). Figure 115 shows the disposition of an underground hangar

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in a morainic landscape when the hill is composed of strong, waterless, rubbly, clayey soils.

Troop water supply in the zone under examination ordinarily presents no difficulties, since the alternation of water-bearing and water-resistant strata (interglacial sands, moraines, etc.) makes it possible to utilize subsoil waters of good quality and sufficient quantity from shallow excavation and tubular shafts.

A good example of the engineering organization of an area situated on the limits of a glacial-accumulative region is the German Army's "Demyanskoe Fortress" or "Demyanskoe defensive base of operations," which had a diameter of as much as 50 kilometers and a perimeter of roughly 200 kilometers. Situated on the edge of the Northwestern Front, this was captured by our troops in 1942.

The western part of this territory lay in the Ilmen Plain, which has a wooded, marshy nature. The eastern and southeastern parts of the base of operations were adjacent to the Valdai Highlands and were characterized by an insignificant marshiness, the presence of lakes and, in certain sectors, by thick mixed forests. Altogether, the whole region fell into the zone of glacial-accumulative relief, connected with the last glaciation, on the margin of whose relief such elements as terminal moraine ridges, basic-moraine landscape and, in places, old lake deposits, etc., are distinguishable.

In their general structure, the fortifications of the perimeter of the Demyanskoe base of operations consisted of strong points for each platoon, company, and in some cases battalion, from which the intervening areas could be observed and shelled. The general structure of the defensive strip may be seen in the diagrams (Figures 116 and 117).

The Germans made full use of natural conditions of the area in their organization of defense. In the selection of their main line of resistance they utilized the lake sectors, marshes, and forest masses. Firing points were disposed on the commanding heights, which afforded a good view, permitted shelling the terrain lying in front, and secured a protected rear.

The enemy made wide use of trenches on the forward edge at the topographical crest or very close to it (Figure 118). Such a disposition justifies itself in cases of defense under conditions of medium broken terrain, especially that which is presented by an accumulative-glacial relief. The organization of defense of the base of operations in wooded and marshy lake areas was primarily antipersonnel, not antitank, since the use of tanks was made difficult by the natural peculiarities of the region.

Characteristic of the organization of the area was the elaborateness of the trench system, which was suitable for the ground and hydrogeological conditions of the terrain (Figure 119). The enemy used the protective nature of the terrain -- its brokenness, and in places its vertical, growing cover -- for camouflaging its artillery installations. Overhead cover and dugouts to conceal personnel were constructed mainly on the reverse-side rocks of the various hills or in hollows near the forward edge.

Along the latter there was a system of open firing positions for rifles and machine guns. The firing positions were connected by a general trench. In order to create flank or cross fire before the forward edge, the enemy disposed his fire beyond the salients and fractures of the trenches. To accomplish this, he pushed forward support points and separate positions. It was characteristic that many support points of the first line had no all-around defense and consisted of a few rows of trenches, echeloned in depth. The flanks of these support points were covered by fire and obstacles.

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All the elements of the defensive base of operations, its fortifications, its garages, and various other structures were successfully adapted to the terrain. This was especially true of the firing positions, which contributed to the strength of fire power and the general technical stability of the enemy's defenses.

In conclusion, it must be noted that a glacial-accumulative region is generally rich in emergency /locally available/ construction materials, particularly boulders, gravel, and sand. The search for these materials is greatly facilitated by their connection with the various geomorphological elements.

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II. WORK IN A DESERT PLAINS REGION

The chief characteristic of a desert region is its climate, which imposes its imprint on all its other traits.

From this point of view, a desert region is characterized first of all by the slight amount of atmospheric precipitation (less than 200 millimeters), the irregularity of rainfall, sudden fluctuations of temperature, great evaporability, and excessive quantities of precipitation followed by sudden droughts.

A desert landscape gradually emerges into a steppe landscape. Between the two lie semideserts, which are characterized by transitional tracks and moderate climatic conditions. The processes which are peculiar to desert regions in many cases lead to the formation of level expanses, whose lithological covering is the function of the original, petrographical composition of the original strata, which have been chemically and mechanically changed.

A great part of the products of the decomposition of the original strata (the decomposition is continuous and on a large scale) remains in the desert region, in most cases without an outlet. Rubbly material, transferred temporarily by active streams, is for the most part accumulated on the margins of the given region. The complex of friable deposits of the zone is characteristic: proluvial deposits of varying composition, deposits of dry deltas and of alluvial fans. accumulations of eolian deposits, loess strata, which have a very complicated origin, specific deposits of drying-up lakes, such as "bidaiki," "sory," "takyry." etc. No less characteristic is the accumulation of rubbly formations. All these various continental deposits present different types of desert (sandy, clayey, rubbly, small arid mountains etc.).

Hydrologically, a desert region is characterized by periodic atmospheric precipitations of "closed" flow whose maximum fall is confined to a short season. A steppe region, however, is characterized in this respect by the presence of an "open" flow? All this, taken together, conditions the presence in these zones of characteristic elements of meso- and microrelief: steppe saucers [bowls?] flat depressions, which have been called "limany," "delly," various forms of sandy, accumulative relief (sandy hillocks, stratified sand, piled-up sand, etc.), numerous depressions in the form of sory, takyry, "pouches," and others, representing temporary and permanent water reservoirs, etc.

From the hydrogeological point of view, the region described above is a clearly defined belt of zonality of subsoil waters and of their chemical composition, which depends on the relief, the climate and the lithological composition of the water-bearing strata.

The unevenness of desert steppes lends itself to the establishment of tactical defense zones. By its structure, a defense zone is composed of various centers of resistance and support points, established on the principle of all-around defense. Defense is organized, as a rule, around inhabited places and sources of water supply.

Tanks assume a very important role in combat on desert plains. Often in defense operations, tank support points are created, in which tanks are used as fixed firing points. The points are equipped with trenches and concealment; the tanks' wide field of fire is exploited and all-around defense is secured.

Technical [engineering] work on a desert terrain presents great difficulty and is distinguished by many special peculiarities.

In the construction of fortifications, it is necessary to make use of the natural conditions of the terrain when the line of defense is chosen and firing points are disposed. The terrain is usually slightly broken, quite exposed to ground and aerial observation, and accessible for troop movements in almost any direction, without depending on roads. Such conditions sharply increase the importance of artificial reinforcement of the area and increase

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the volume of engineering work.

It is advantageous to have quicksands in front of firing positions. Antitank obstacles are built on the margins of the quicksands. If the sands prove to be partly packed and substantial, they are loosened up for large obstacles. In reinforced strong points it is necessary to secure the flank especially firmly. This is achieved by constructing trenches and covering them with various natural and artificial obstacles.

Fortifications which are constructed to answer tactical problems must be built in such a way that the physical-geological processes operative in the desert do not threaten their destruction. Among such processes are, for example, periodic freshets which may bring down from near-by mountains a great quantity of rubbly material and cause devastating destruction. It is the duty of the geologist to determine unflooded sections and areas for protective dikes. The construction of fortifications varies in accordance with the character of the strata. In sandy soils, which are widespread in desert areas, revetments are used to strengthen the hollows. For one-man fox holes, gabions may be used; various desert plants such as the holoxylon, etc., are used for the revetment of trench walls. Sub-breastwork covers and shelters can be constructed only in tightly packed sand with revetments of ready-made frames. In dealing with clayey and loess strata, the slope of the excavation does not require reinforcement.

The geologist must take into account the engineering-geological peculiarities of loess strata, which have various origins (eolian, alluvial, proluvial, deluvial) and are widely distributed not only in the territory of the USSR, but in the adjacent countries of Europe, Middle [East?], and Central Asia. These soils are distinguished by a high water permeability, a small volumetric weight (from 1.0 to 1.6 [unit not given] and less), a great porosity (from 40 to 56 percent), slight capacity for liquefaction, established according to Atterberg on the margins of the lower range of fluidity 25-30, plasticity according to Atterberg from 7 to 15, a great height of capillary rise, and rather significant sinking under pressure in moist conditions.

Loess strata have a peculiarly weak resistance to erosion. When thoroughly wet they often sag or lose their firmness. The faces of precipices and vertically excavated walls do not require revetment, but when preparing in advance constructions which will remain in service for a long time, the slopes of trenches are smeared with a thin coating of dissolved loess [silt] with the addition of slaked lime (10 percent), or finely chopped, soft straw (straw grass, feather grass). Such a coating protects the slopes from destruction in time of rain. Often turf, which is used in other places, is replaced by sun-dried bricks, which are prepared on the spot. The bricks are laid over the coating of silt and clay.

The erection of fortification constructions in desert regions is made difficult by the lack of construction materials, wooden materials in particular. Therefore, in unforested regions, wide use is made of reeds, brushwood, sedge, straw grass, and other kinds of tough grasses, together with silt, clay, and other soils. From these materials it is possible to construct flat, dome-shaped, and vaulted protective coverings for firing installations, which are covered with packed dirt. Firing points, communications passages, shelters, etc., can be constructed in this way. In the case of rocky strata in desert climatic conditions, natural recesses, niches, grottos, and caverns can be used by the troops for shelters, storage, medical aid, firing points, etc. Generally in the disposition of these caves, a definite uniformity can be observed, which is connected with the lithology of the strata and often with the exposure of the slopes. This uniformity should be brought to light by the geologist and reported for the information of the command.

Desert regions are not traversable with equal facility in all directions. Routes of travel are dictated by the micro- and mesorelief, and in many cases military roads must be constructed. The geologist's part in these cases is the clarification of the peculiarities of the relief of the desert steppe, giving advice on laying out the cross-country route of march, clarifying the traversability of roads at the various times of the year, etc.

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It is convenient to dispose underground hangars in those sections of an area formed by thick loess strata, which are easy to work.

In the case of wide, sandy stretches, the traversability depends upon the character and firmness of the sands. In regions of loose sands, the roads must be reinforced. This often slows down considerably the ordinary rates of movement of military equipment and other means of transportation. Sand relief in the form of piled-up, stratified sands and sandy hillocks, also plays a great part; for example, sand ridges disposed more or less parallel to each other at about 30 - 200-meter intervals, generally have symmetrical slopes and range in height from 2 or 3 to 30 meters. The steepness of the ridges increases in proportion to their bulk and in the highest ridges exceeds 20 degrees. These factors make movement across the ridge much more difficult, both for motor-mechanized transport and for infantry; consequently, such a direction of march must be avoided as much as possible. Movement along the sand ridges and through the passes between the ridges is fairly simple and has the advantages of providing camouflage for the march. On the margins of clayey deserts, varied sectors are encountered. In clear weather, roads over clay and loess strata are generally very dusty but traversable. "Takyry" sections are similar. However, in rainy weather, "takyry" become thoroughly soaked, like other clayey soils, which necessitates road work. Saline soils are quite impassable, particularly in the rainy period.

In many cases in desert regions, one finds very broken relief, as the result of erosion processes, in the form of sharply serrated, deep gullies and wash-outs with almost vertical walks (from 3 to 5 meters deep). In certain places, these eroded furrows are so numerous (sometimes they number up to 150 per kilometer, that is, one every 7 meters) that the relief takes on the character of badlands and is almost untraversable.

In view of the nearly total absence of surface waters in desert regions, the importance of military-hydrotechnical works assumes a very special nature and includes the construction of dikes to channel swollen streams, the construction of kyarizy [galleries 7], etc.

Water-supply work increases immeasurably under these conditions. The success of military operations in a desert is completely dependent on the supply of water. This is shown by military operations in North Africa, Abyssinia, and other places. For example, in 6 months of war in Abyssinia the Italians sank up to 13,000 artesian wells, some of which reached a depth of 130 meters.

The geological structure of desert regions usually favors the accumulation of subsoil waters. Mechanical properties are very important to their accumulation, since the speed of infiltration of atmospheric precipitation is a decisive factor in the accumulation of subsoil waters. In the majority of desert regions there is widespread accumulation of sandy and rubbly material of varied origins, which, like a sponge absorbing moisture, creates at a certain depth a water-saturated zone. From the point of view of origin, the following types of subsoil water are to be distinguished in desert regions (according to V.A. Sergeyev):

(1) Artesian and subartesian waters in the original deposits, which are fed by the entrapment of moisture outside the desert zone

(2) Infiltration-condensation waters of the sandy masses and stony, alluvial deposits

(3) Filtration waters of the littoral dunes, alluvial flatlands, and gullies of the wadi type of river valley

(4) Infiltration waters of dry depressions: sory, takyry, limany and other depressions.

The geologist servicing troops in desert regions must solve the difficult problem of troop water supply, for which it is necessary to have a basic

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acquaintance with the geological conditions of the area. In most cases, subsoil waters are used; deep artesian or subartesian waters are obtained less often since their extraction involves a long time. The different types of desert regions confront the geologist with varied problems.

Under clayey desert conditions with drainage, subsoil waters are generally characterized by a great variety in chemical composition and in depth of occurrence.

Depending upon the flow of subsoil waters and the outcropping of the water-bearing strata in gullies, ravines and dry valleys, salts are transferred to the local closed-in depressions and the latter become saline. The high percentage of chlorine in solution in inland depression waters, which is derived from the easily transportable chlorine strata, is very variable. The quantity is more or less constant, or decreases in inverse proportion to the mineral content. Similarily, sulfates are also distributed irregularly. Generally, the degree of mineralization increases in successive stages from the periphery to the center of the depression.

The character of subsoil waters is often connected with the hydrography of the area, but reflects climatic influences slightly. After establishing the geological structure of the area, the geologist directs the search for fresh water, the least exposed to salification, at the places on the watershed expanse where favorable conditions for the emergence of fresh water exist. The geologist must remember that in undrained sections of a clayey desert region there are other hydrogeological conditions. As rule, waters of such regions are always mineralized. With an increased mineral-matter content, the result is a small flow of subsoil waters. In mineral content, chlorides occupy an important place and exceed the sulfates. In most cases, the depth of the subsoil water table is not great; however, it may reach 20 to 30 meters.

In desert steppes and regions which are drying up, various types of depressions are found, which bear various local names: sory, takyry, limany, bidaiki, etc.

All of them, generally, constitute temporary water reservoirs and are characterized by varying hydrogeological conditions.

Certain of these depressions have fresh subsoil waters, as for example, most limany and bidaiki; others, such as sory, are salty.

The freshness of the water found in the first two types depends upon the infiltration of atmospheric precipitation, which generally immerses the limany in the springtime. Very often, at a certain depth, the fresh water mixes with the mineralized water. The subsoil waters of limany and bidaiki most frequently lie on the "linz" or thin intercalation of clayey or sludgy deposit. Sometimes the water-bearing strata of "limany" are quicksands. "Sory" present another picture. They are usually accumulators of salts. For example, "sory" have strong mineralized subsoil water or mineral mud lying right at the surface. Sory, collecting water from surrounding regions and being partly fed by mineralized subsoil waters, accumulate salts and contribute to the salification of the soils and subsoil waters. The geologist who is concerned with problems of water supply in desert regions must be able to distinguish temporary water-reservoir depressions of the various types from their outward geomorphological characteristics, and determine the depth of the water table and the quality of the subsoil water. One of the most important characteristics indicating the depth of the water table is, as is generally known, the vegetation which has been called "freatofit." This includes sedge [or slough grass], rushes [or club grass], reed mace [or cat-tail flag], reeds, and many others. In many cases, this vegetation is in strict zonality in accordance with the depth of water table and partly with the degree of its mineralization.

On the margins of development of sandy deserts are found very easily accessible waters, which are frequently satisfactory. In most cases they are

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characterized by a carbonated salification; their mineralization is often negligible. These waters are widely utilized by means of wells. The area occupied by subsoil water is closely related to the meso- and microrelief of the surface. When there is complicated surface micro-relief, a definite mosaic of depth of water table can often be observed. The geologist must be able to determine the approximate depths of occurrence, basing his findings on a number of outward characteristics.

Finally, wide use may be made of subsoil waters connected with alluvial and proluvial deposits, dry delta deposits, and alluvial fans. Their character, depth of occurrence, degree of mineralization, as is known, depends upon the hydrogeological behavior of the stream and the type of the basin: whether the stream is "transit" (for example, the Syr Darya River) or is entirely within the desert zone and is only a temporarily active stream. The geologist's duties, therefore, include the clarification of the region fed by the given basin, its behavior, the exposition of the regularity of depth of water table, the relations of the subsoil water with the geomorphological features of the bottomland and the other elements of the river valley, the correlation of the subsoil waters of the alluvial stream with the subsoil of the bottomlands, river terraces, etc.

In view of the great variability of the surface relief of sandy regions, especially the meso- and microforms, the choice of platform as a foundation for an airdrome is not always easy to make. Various types of deserts and semideserts are characterized by various morphological landscapes, and at the same time are distinguished by varied possibilities. As B. A. Fedorovich points out: "In some regions of sandy desert, airplane landings are impossible when there are dunes 3 to 5 meters high or if the relief is pitted and packed, since the sand is broken into such small fragments that it is impossible to find a landing strip for even the smallest or slowest plane. However, in places where the sandy areas are covered by takyry, the deserts offer valuable, ready-made landing fields, as good as asphalt." The quality of these natural landing fields often changes during atmospheric precipitation, especially when they are soaked with rain.

It is convenient to locate underground hangars in sandy dunes (Figure 121). Tracts of salt marsh are almost ruled out for the construction of landing fields.

In solving problems concerning the platform under landing fields, the geologist must analyze the relief, distinguish its elements and give their characteristics. In a sandy desert, the micro- and mesorelief features are at the same time indicators of the wind direction. According to the data of B. A. Fedorovich, there exists a definite relationship between changes in the behavior of winds and sand relief. The military geologist disclosed that relationship.

In analyzing the relief of sandy areas, the geologist may indicate those places which, from the point of view of the surface structure might be suitable for landing fields but which in relation to landing conditions present a definite danger (for example, landing planes in synclines [basins] in the autumn or the hot season of the year).

The peculiarities of deserts must also be considered from other points of view. For example, under hot climatic conditions, cooling accommodations must be provided for planes and motorized transport, which in many cases means the necessity of increasing the water consumption.

For another thing, in desert regions dust suspended in the air tends to cause motors to wear out quickly. There were cases in North Africa, for example, where German planes knocked out by the English in 194? revealed worn-out motors, in spite of the fact that they had had only 30 hours in the air. Therefore, in such regions only a part of the airplane strength can be put into action, while the rest is grounded for overhauling. By taking a number of measures (using sand filters, etc.), the percentage of active-duty planes can be made quite high. Thus, for example, the English in North Africa in 1942 brought that percentage to 80 or 90, while for the Germans it rose only to 30.

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In carrying out military-geological surveys and prospecting and gathering data on future theaters of combat, the geologist must take into account these circumstances and inform the commanding officer in good time.

Camouflage must be widely-used in desert steppe conditions. The color of the sand must be strictly observed and imitated; in most cases it depends upon the geological structure and physico-geological processes.

The commanding officer must be clearly aware of the sculpture and pattern of the region in order to camouflage the mechanical equipment and troop formations correctly.

Consequently, it is the geologist's problem to point out segments of roads in desert steppes, which are dangerous from the point of view of detection.

Every commanding officer in offensive operations must know not only the types of ground he will meet on the margins of a given direction but also all peculiarities of relief, particularly the microforms, which may be widely used for camouflage by individual troops in offensive operations.

As has been observed earlier, the interpretation of aerial photographs is one of the most highly recommended means of obtaining the various data for each region, bearing not only upon the layout of its surface, i.e., the relief, but also upon its structure, the peculiarities of its soil covering, presence of wells, etc.

Due to the combination of natural conditions (climatic factors, the almost complete absence of vegetation, etc.), this method, which may be used successfully at any time of the year, may be highly recommended for barren country. It is especially valuable when a much-needed large-scale map of the area of interest is not immediately available.

With a brief examination of the regions described and a clarification of those problems which confront the geologist in the various geological conditions, we restrict ourselves to a characterization of the peculiarities of the geologist's work under the conditions of various landscapes.

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